

Reduction-Oxidation Complex,  
Plutonium Concentration Facility  
(Building 233-S)  
200 West Area, Hanford Site  
Richland Vicinity  
Benton County  
Washington

HAER No. WA-129-A

HAER  
WASH  
3-RICH, V  
3A-

**PHOTOGRAPHS**

**WRITTEN HISTORICAL AND DESCRIPTIVE DATA**

Historic American Engineering Record  
National Park Service  
Western Region  
Department of the Interior  
San Francisco, California 94107

**HISTORIC AMERICAN ENGINEERING RECORD**  
**REDUCTION-OXIDATION COMPLEX,**  
**PLUTONIUM CONCENTRATION FACILITY (Building 233-S)**

HAER  
WASH  
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3A-

**HAER NO. WA-129-A**

Location: 200 West Area, Hanford Site, 20 miles north of Richland, Benton County, Washington.

USGS Gable Butte Quadrangle, Washington-Benton County, 1986, 7.5 Minute Series (Topographic), Section 12, Township 12 North, Range 25 East of the Willamette Meridian.

UTM Coordinates: Zone 11, Easting 299020, Northing 5156740.

Date of  
Construction: 1955.

Engineer: Unknown.

Builder: General Electric Company.

Present Owner: U. S. Department of Energy, Washington D. C.

Present Use: Abandoned; in process of deactivation for removal of hazardous substances, and preparation for decommissioning and demolition.

Significance: Building 233-S, the Plutonium Concentration Facility, was constructed as part of the Reduction-Oxidation (REDOX) Canyon and Service Facility's Phase II Capacity Increase on the Hanford Site. While 233-S is not individually eligible for listing in the National Register of Historic Places, it does appear to merit consideration as a contributing element to a potential historic district centered on the adjacent REDOX canyon building (202-S) as both facilities were closely connected. Located adjacent to the north wall of 202-S, the 233-S building provided final purification and concentration of plutonium solutions using an ion-exchange process. In 1963 a chemical reaction in the exchange column in 233-S resulted in a fire that spread plutonium contamination throughout most of the building. After clean-up the facility was used for concentration of plutonium and neptunium nitrate solutions from the REDOX plant until 1967, when both 233-S and REDOX were sealed off and retired from service.

**Report Prepared**

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## ***HANFORD SITE - MISSION***

In 1943 the Manhattan Engineer District (MED) of the U. S. Army Corps of Engineers selected Hanford, Washington as the site of the world's first plutonium production facilities. The development of atomic power on the Hanford Site represented a significant national event that profoundly shaped and defined military strategies and wartime events during the 1940's. The efforts in research and development at the Hanford Site during the Manhattan Project (1943-1946) through the Cold War period influenced national developments in energy production, medical breakthroughs and plutonium production for national defense.

The mission today is one of environmental remediation, restoration, and waste management. N- Reactor, the last plutonium production reactor in operation, closed in 1987. In 1989, the Hanford Federal Facility Agreement and Consent Order (the Tri-Party Agreement) was signed. The three signatories, State of Washington, the U. S. Environmental Protection Agency, and the U. S. Department of Energy, agreed to a clean-up of the Hanford Site.

## ***200 WEST AREA, REDOX COMPLEX AND 233-S***

The plutonium production process at Hanford involved three essential steps: uranium fuel elements were fabricated and jacketed in the 300 Area, irradiated in the 100 Areas, and chemically dissolved and separated into plutonium, unconverted uranium and various fission byproducts in the 200 Areas. Initially constructed during the Manhattan Project era, the 200 Areas at Hanford were the locations of the chemical separations ("processing") plants and their numerous ancillary and support facilities.

One of the more important groups of facilities in the 200 West Area was the REDOX Complex. The complex initially consisted of the REDOX canyon building (202-S), 211-S Tank Farm, 276-S Solvent Handling Building, 2726-S, 203-S, 277-S, 240-S, 241-S, 207-S, 216-S (multiple), 222-S, 219-S, 232-S, 2702-S, 2704-S and two of the canyon exhaust system structures, 291-S and 293-S. Added later were the Plutonium Concentration Facility (233-S), 276-S, 292-S, 220-S, 2706-S, 2708-S, 2710-S, 2711-S, 2712-S, 2715-S, 2716-S, 2718-S, 2723-SA, 2726-S, 2727-S, and 2734-S.

Constructed in 1951 the REDOX canyon building (202-S) produced final plutonium concentration in the E-16 Plutonium Pre-concentrator, and in the E-17 Plutonium Concentrator. During 1953, however, several deficiencies were identified in REDOX processes. A program of (REDOX Phase II) upgrades and capacity increases was undertaken that resulted in the construction in 1955 of 233-S, the Plutonium Concentration Facility.

## ***REDOX FACILITY PROCESSES***

The REDOX facility at the Hanford Site was completed in late 1951 and became operational with "hot" (radioactive) materials in January, 1952. At the REDOX plant, final plutonium (Pu) concentration was accomplished in the E-16 Plutonium Pre-Concentrator, and in the E-17 Plutonium Concentrator. Both of these concentrators were located in the North Sample Gallery, which was a part of the main 202-S (REDOX) Building. In the E-16 Pre-Concentrator,

the hexone (methyl isobutyl ketone, MIBK, the REDOX solvent) was steam-stripped away, and then a three-fold reduction in volume of the Pu-bearing solution was accomplished. The E-16 unit consisted of a packed column mounted on a tank with a heating coil. Demineralized water in the tank was heated via the coil, as the Pu-bearing feed solution flowed down through the packed column. Approximately 95% of the hexone thus was removed. Following the stripping operation, the Pu solution was concentrated by simple boiling with coil steam. Remaining amounts of hexone were removed at this time via distillation.

The E-17 Plutonium Concentrator also consisted of a packed column mounted on a tank with a heating coil. After cooling in the E-16 Pre-Concentrator, the Pu solution was drawn by vacuum jet through the E-21 Plutonium Transfer Trap into the E-17 Concentrator. Steam then was admitted to the coil, and the Pu solution was heated to boiling and concentrated for approximately 110 minutes. Solution droplets from the vapor stream were entrained in the column, but any that was lost to steam condensate was caught in the E-18 vapor condenser that was connected to the column vapor outlet, recycled, and sent to re-work. In the E-17 Concentrator, the Pu solution was boiled to the final PR (product) can volume of about eight gallons, and transferred directly into the cans via a filling line. Each can then was plugged with a metal stopper surrounded by a teflon gasket to provide a vacuum seal, and encased in an outer carrier vessel. This entire vessel was placed in a special truck-mounted carrier, and transferred to the 231-Z Plutonium Isolation Building or the 234-5 Plutonium Finishing Plant (PFP) for final processing. In all of the above concentration operations, as well as in the final Pu nitrate product form, the plutonium was in the +6 valent (hexavalent) state.<sup>0</sup>

## **CONSTRUCTION OF 233-S**

### **REDOX PHASE II CAPACITY INCREASE**

As mentioned above several deficiencies were identified by Hanford operators in the overall REDOX processes. A program of upgrades and "capacity increases" was undertaken throughout the next three years. As a part of the REDOX Phase II capacity increase, the 233-S Plutonium Concentration Building was designed and constructed.<sup>1</sup>

### **PLUTONIUM CONCENTRATION PROCESSES**

Plutonium concentration actually took place in the equipment cell, and consisted of the same basic hexone stripping and concentration by boiling that had taken place in the original process in the North Sample Gallery of the 202-S Building. Plutonium solution was fed into the L-2 stripper, where the hexone was steam stripped and a 5-35 percent product concentration (by volume) was achieved. Full concentration to the desired Pu level then took place, again via steam heat and boiling, in the L-3 Product Concentrator. A greater concentration level was needed, and achieved, than had taken place in the North Sample Gallery, but the basic mechanism was the same. The product then was filtered and sampled, and transferred under vacuum into new-style PR cans. (The older style cans also were used, but now were known as "recycle" or RC cans.) Condensate and vapors were collected, recycled, and sent to re-work in and from vessels L-10 (Condensate Receiver), L-11 (Concentrator Condenser), L-12 (Condensate Evaporator), and L-13 (Evaporator Condenser).<sup>2</sup>

In the meanwhile, as the REDOX capacity increase programs were going forward, new concepts and methods in plutonium concentration were being developed elsewhere. In a paper delivered at the 1958 International Conference on the Peaceful Uses of Atomic Energy, and in a

1959 Hanford Works document, chemists J. L. Ryan and E. J. Wheelwright outlined the new procedure. Plutonium in solution in the +4 valent (tetravalent) state, in strong (approximately molar) nitric acid, was passed through a column of organic anion exchange resin. The resin normally was based on a polystyrene or a polyvinylpyridine structure. The tetravalent Pu was strongly absorbed into the resin beads as an anionic nitrate complex, while the solution and virtually all impurities passed on through the column. The rare ability of plutonium to form a strong anionic nitrate complex was the key to the high purification achievable with this method.

After plutonium absorption, the resin was "washed" out with molar nitric acid to remove all of the feed solution and its contained impurities from the resin bed. Such impurities included iron, aluminum, fission products and others, in cation form. Next, the Pu was stripped (or "scrubbed") from the resin using dilute (0.3 - 0.5 molar) nitric acid. The anionic plutonium complex was not stable in such dilute acid, and the Pu came off of the resin as a cationic species. In order to greatly increase the potential process throughput, the process was operated at 50-60 degrees C. At these levels, plutonium absorption and desorption rates were much higher than they were at 25 degrees C. The results of the new Ryan-Wheelwright procedure included decontamination factors, and product purity and volume concentration levels far above those produced by simple evaporation.<sup>3</sup>

#### HIGGINS CONTACTORS SYSTEMS

In order not to require numerous duplicate columns of critically safe dimensions with complex valving and piping between them, the process was applied in semi-continuous "moving bed" ion exchange equipment known as "Higgins contactors".<sup>4</sup> In this apparatus, named for the individual patent-holder who carried out much of the early development work at the Oak Ridge National Laboratory, the resin moved in an intermittent manner around a loop of pipe (column) having sections for resin loading, washing, elution of product and a resin holdup reservoir. In other words, the resin was pulsed through the plutonium solution, rather than the solution moving through a resin column or bed. In this system, plug valves in the resin loop opened about every 20-30 minutes, and an electrically controlled hydraulic pulse on the resin reservoir moved ("pushed") resin around the loop for about 20-30 seconds. Times could be varied as necessary, to coincide with throughput needs. A typical push introduced and moved about eight inches of resin, and excess resin went into a catch tank. The plug valves then closed, while feed, wash and eluant valves opened. Another valve opened to drain resin from the catch tank to a resin reservoir. Until the next push, the various segments of the ion exchange column loop acted as static beds, performing absorption, washing or elution functions just as in fixed systems.

The Higgins system had many advantages over multiple fixed or static ion exchange columns, including lower resin inventory, lower chemical consumption, lower solution and plutonium recycle, lower resin radiation damage per unit of throughput, lower operating costs, decreased operating complexity and space requirements, higher average product concentration, and better contamination control. Additionally, resin particles could maintain their positions relative to each other, thus assuring greater uniformity of product. Also, the "scrub" or aqueous flow was not limited because of solution density or the possibility of fluidization of the resin. The ion exchange product was about 40-50 grams of plutonium per liter. It was concentrated further, prior to loadout, by a factor of five to seven, in a small, corrosion-resistant titanium tube bundle concentrator.<sup>5</sup>

In 1958 at the Hanford PUREX (plutonium uranium extraction) facility, the first working, plant-scale anion exchange process for plutonium concentration and decontamination was placed in use. The new process used a Higgins contactor, and was considered a prototype at the time. It allowed PUREX to convert from a three-cycle to a two-cycle process, because the anion exchange method substituted for the two final plutonium concentration steps.<sup>6</sup> The anion exchange method worked so well in PUREX that it was replaced with a larger unit in 1960, as part of a series of "reliability improvements" at the facility. Together, these improvements allowed the PUREX Plant to operate at a 3.6 "capacity factor;" that is, to process nearly 30 metric tons (MTU) of aluminum-clad uranium fuel elements per day. Such productivity was greater by far than any previous routine capacity. The resin column in the new equipment was about 5.29 inches in inner diameter (I.D.), and the contactor was equipped with a new resin reservoir, receiver, push tank, resin addition lines, and transfer lines.<sup>7</sup>

#### IMPROVEMENTS AT REDOX AND 233-S

By 1961, production gains were progressing so well at the PUREX Plant, the mainstay of Hanford Works and national plutonium production, that similar improvements were funded at the REDOX Plant. Along with enhanced Pu production through conversion to the anion exchange method of purification and concentration, neptunium 237 (Np-237) production was begun at REDOX. Code-named "birch," "palm," or sometimes "brandy," Np-237 already was being produced at PUREX. The necessary modifications to enable birch production at REDOX, and to convert the plutonium concentration facilities to the anion exchange process, were combined into Project CGC-913 and centered in the 233-S Building. Scope design was begun in late 1960, actual construction took place during 1961-62, and the refurbished 233-S facility re-opened, with its new capabilities, in mid-1962.<sup>8</sup>

Also, much new monitoring instrumentation was added to the 233-S Building, including neutron and alpha monitors and a gamma absorptiometer used to measure the density of the material at one point in the extraction section of the L-18 Contactor.<sup>9</sup>

#### *FIRE AND CONTAMINATION IN 233-S*

Throughout the early history of the 233-S Building, very few contamination events occurred. The most serious was the backup of product solution through a defective valve, into an airline that led into the control room, on June 18, 1956. Two employees were seriously contaminated, several others were mildly contaminated, and ground contamination was detected up to 5,000 disintegrations per minute (dpm) over an estimated 200 square feet just outside the dampers and door of the building.<sup>10</sup>

However, on November 6, 1963, after the new Plutonium Anion Exchange Contactor and Birch Recovery Program had been operating only about 18 months, a serious fire occurred in the 233-S Building. The incident began with a sudden reversal of air flow into the operating gallery. The air reversal resulted from venting of the over-pressurized Higgins contactor through a flange with a ruptured gasket. However, the cause of the pressurization of the contactor is unclear. Approximately 20 minutes later, fire was observed in the building. It burned through open floor grating to involve all four floors of the facility as well as the anion exchange contactor. Canvas clothes hampers full of coveralls, gloves, caps, hoods, and shoe covers burned on all floors, as did rubber shoes and paper floor covering. The Higgins contactor itself was severely burned although not fully consumed. The fire was extinguished in about 90 minutes, through the use of sodium

bicarbonate. According to the investigation report, alpha contamination was "rather widely spread throughout the 233-S Building." The REDOX Plant and 233-S were shut down for approximately six weeks, while isolation, partial decontamination and cleanup took place.<sup>11</sup>

### ***CLOSURE OF REDOX AND 233-S***

Conclusions as to whether or not the Higgins contactor caused the fire, or was over pressurized as a result of the fire, were difficult to assess. The Investigating Committee concluded that "there was still no positive evidence" to decide that question, and "no definitive explanation of the underlying cause in either case." The final report stated that "most of all of the energy necessary to pressurize the column must have come from some source other than an external fire. This does not prove that an internal chemical reaction provided the energy, nor does it exclude an external fire as a triggering mechanism for such a reaction."<sup>12</sup> The REDOX Plant and 233-S resumed operations on December 22, 1963, but without the use of the plutonium anion exchange process or equipment. Final plutonium concentration for the plant then took place with the product going directly from the L-12 Concentrator into the L-3 Concentrator. The Higgins contactor never ran again in the 233-S Building. Both the REDOX Plant and 233-S were shut down at the beginning of 1967.<sup>13</sup>

### ***PHYSICAL DESCRIPTION***

#### **ORIGINAL PLANS AND MODIFICATIONS/EXPANSIONS OF 233-S**

233-S is a rectangular (29' x 85'), concrete and corrugated metal (paneled) clad building, located adjacent to the north outside wall of the REDOX plant (toward the west end). The roof line fascia was covered with copper, and attached exterior metal ladders provided access to the rooftop. 233-S initially contained seven rooms: an equipment cell, operating gallery, loadout room, storage room, change room, wash room, and blower room.

In 1957, modifications and expansions were authorized for the 233-S Building. However, the basic plutonium concentration equipment and process did not change. During late 1957 and early 1958, a new, electrically-powered exhaust blower and a new filter unit were procured and installed to act as spares for the existing 233-S exhaust system. These improvements were to provide greater contamination control, and to insure the continuity of operations in the event of failure of the primary exhaust system. Further, grated platforms were constructed on three levels above the ground floor in the maintenance alley of the equipment cell (adjacent to the plutonium concentration equipment), to allow for easier and safer maintenance operations. To provide stairwell access to the three levels an insulated, metal paneled I-Beam addition was constructed onto the east facade. Completed in 1958, the addition provided metal-grated stairwells for interior access to the different levels. Previously interior access was by a hydraulic lift.

An additional modification provided for the building of another storage room, to the north of the existing storage room, as well as a larger truck unloading dock. Additional product storage space was needed because REDOX was moving into its Phase III Capacity Increase program, and because recycled material from the 234-5 Building (PFP) now was being sent back to the REDOX Plant for re-work via the 233-S Building. Such a procedure for the storage of re-work material from PFP had not been in place when the original 233-S Building was constructed. The new

storage facilities more than doubled the storage capacity of the 233-S Building, from 28 to 64 PR and RC cans. The above modifications to the 233-S Building were completed in April 1958.<sup>14</sup>

The most major piece of new equipment installed in the 233-S Building during Project CGC-913 was the L-18 Plutonium Anion Exchange Contactor. It consisted of an 18-foot tall, two-foot wide, flanged loop of four-inch pipe. The receiver section extended above one leg of the loop by an additional six feet. The greenhouse portion of the 233-S Building was extended on the east end by 2.63 feet by 3.75 feet by 32 feet (height), and the contactor was mounted vertically in the greenhouse. Other new equipment included the L-1 feed tank, a six-inch (diameter) vertical pipe, 20 feet long, that replaced the previous, three-foot diameter feed tank that could not provide criticality safety in the new system. Also new was the L-3 Product Concentrator, a four-piece flanged concentrator loop and de-entrainment tower made of titanium. Removable, titanium tube bundles encased in a stainless steel shell within the tower actually performed final concentration of the Pu from the L-18 Higgins contactor. A new L-16 Recycle Tank (three vertical pipes six inches in diameter by 56 inches tall) received any recycle (off-standard) Pu solutions that needed re-working.

Extensive piping changes also were made during Project CGC-913, and several pieces of existing equipment were modified to perform new functions. Specifically, the 3A and 3B columns were withdrawn from plutonium purification service, and converted for neptunium purification. The L-2 Concentrator, originally a hexone stripper for plutonium product solution, was modified to serve as the brandy product concentrator. The L-8 Brandy Concentrator Condenser and the L-21 Brandy Load-Out Tank also were modified, as were the L-4 Product Receiver Tank, the L-6 Product Sampler, the L-7 PR Head Tank (through which the PR cans were filled under vacuum), the L-9 Condensate Sampler, the L-10-F Product Feed Tank, the L-10-W Waste Receiver Tank, the L-11 and L-13 Concentrator Condensers, the L-12 Product Feed Concentrator, the L-14 Product Transfer Trap, the L-15 Jet Condenser, and the L-22 Recycle Monitoring Tank.

#### EXISTING CONDITIONS

The Surplus Facilities Program has listed 233-S as a high priority for deactivation and decommissioning, and eventual demolition, due to extensive plutonium concentration within the building. The decommissioning activity would consist of the dismantling, size reduction, decontamination, packaging and removal of all interior equipment, interior pipes, and duct work. The interior walls would be decontaminated, followed by disassembly, packaging and disposal of the building.

Today, 233-S contains an equipment room, pipe gallery, control room, P. R. Can Loadout and Decontamination Room, two CAN storage rooms, Special Work Procedure (S. W. P.) change room, and a 32-foot high section that houses Process Hood Areas No. 1 & 2. A plexiglas wall divides the two hood areas: Process Hood No. 1 provides a viewing area into Process Hood No. 2. East of No. 2 a three level platform, as noted, was constructed above the ground floor in the maintenance alley of the equipment cell (adjacent to the plutonium concentration equipment) to allow for safer maintenance operations.

The facility was retired in 1967 after process flushing/washdown. All equipment and machinery has been removed from the Can Storage Room, P. R. Can Storage Room, S. W. P. Change Room, and the Ventilation-Equipment Room. All the main process equipment in the



Process Hood (Area No. 1), however, is in-place, including the Ion Exchange column (L-18) and miscellaneous concentrators and condensers. Two load-out vessels were removed from the load-out hood during the 1979 decontamination and decommissioning effort of the loadout room. The view into the loadout hood, however, has been covered over. The control panel in the control room, which originally directed the operations and valves in Process Hood No. 1, is still intact.

### **PROJECT INFORMATION**

Due to public health and safety concerns the U. S Department of Energy, Richland Operations Office (RL), is planning to demolish the 233-S Plutonium Concentration Facility in the 200 West Area. RL determined that maintenance and surveillance costs were increasing due to extensive plutonium contamination within the building, and the risk of potential release of plutonium was unacceptable. The Environmental Restoration Contract (ERC) program has listed this facility as a high priority for decommissioning and decontamination, and eventual demolition.

The State Historic Preservation Officer (SHPO) concluded that while 233-S is not individually eligible for listing in the National Register of Historic Places, it does appear to merit consideration as a contributing element to a potential historic district centered on the adjacent REDOX facility, as both plants were closely connected not only in location but also in operation. Therefore, RL concluded that the above undertaking will have an adverse effect upon the National Register eligibility of the potential historic district in the area.

Section 106 of the National Historic Preservation Act of 1966 (P.L. 86-665, as amended) requires all federal agencies to take into account the effects of their undertakings on properties listed in or eligible for the Register, and afford the Advisory Council on Historic Preservation an opportunity to comment on the proposed undertaking. As required by Section 106, RL entered into a consultation process with the SHPO and the Advisory Council to negotiate a Memorandum of Agreement (MOA) on means to avoid or mitigate the adverse effects of the proposed undertaking. The MOA stipulated that RL mitigate the adverse effects by documenting the building to Historic American Engineering Record (HAER) standards. The stipulations in the MOA include a HAER narrative report, archival-quality photographic documentation, and photographic copies of original construction/engineering drawings.

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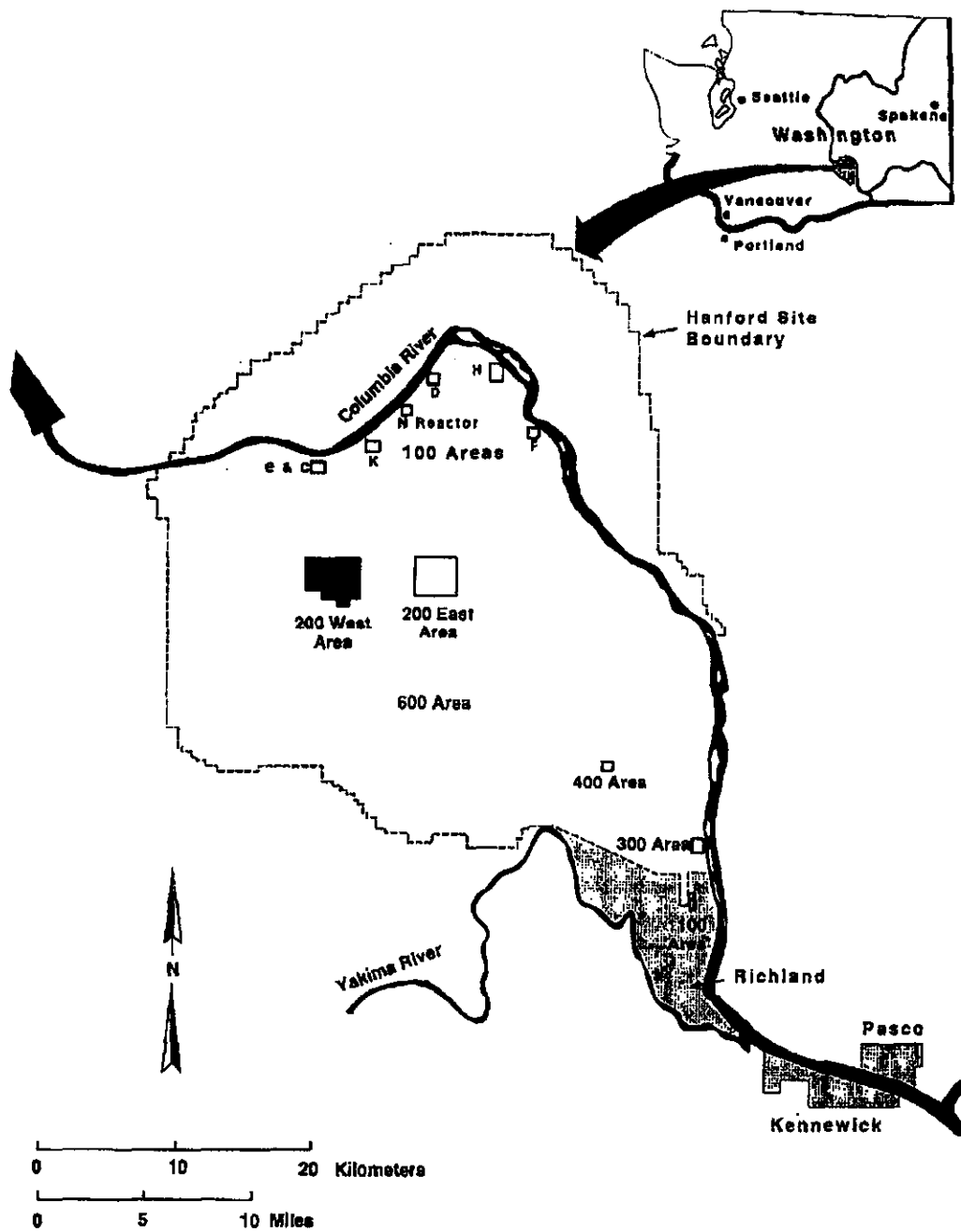
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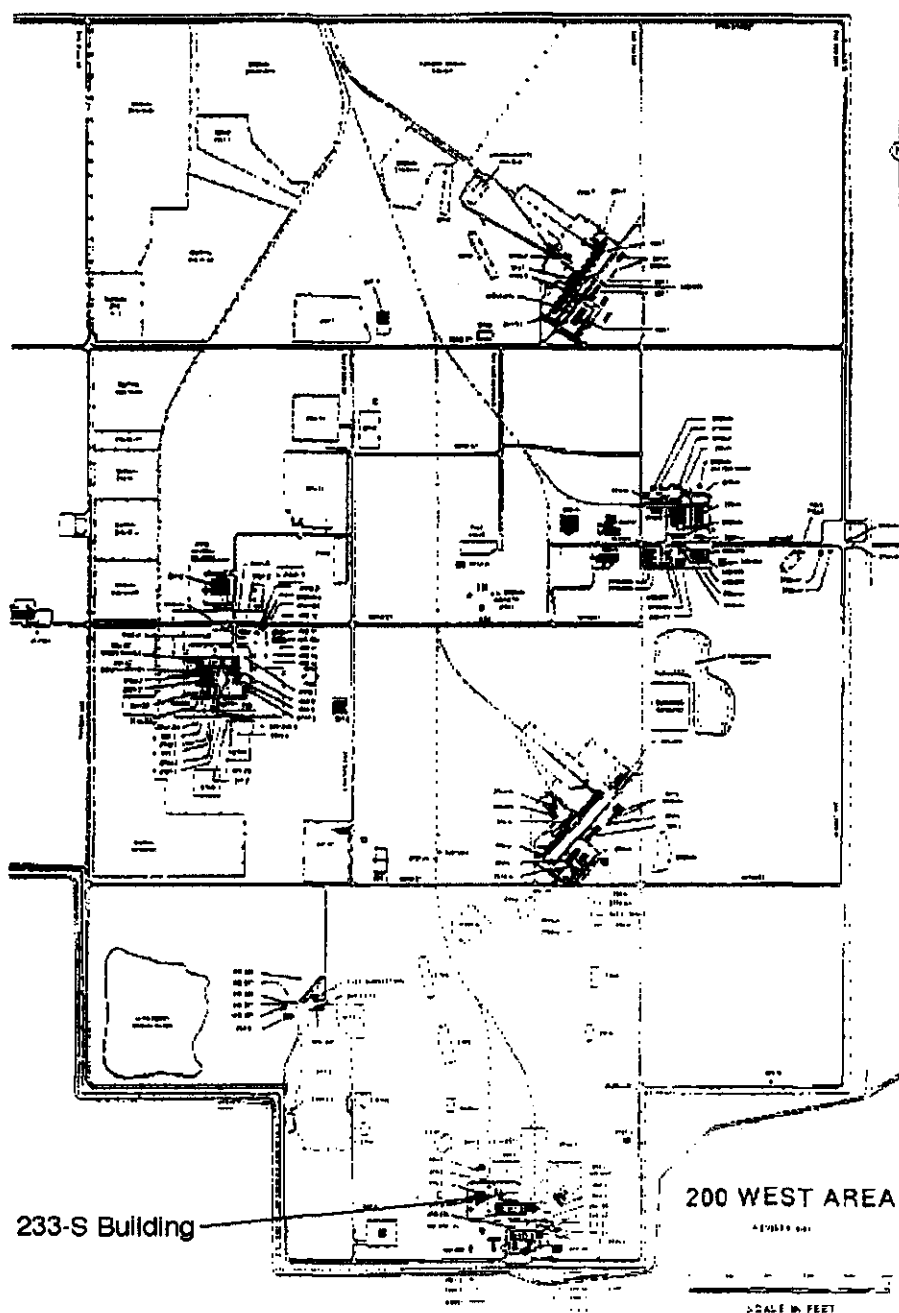
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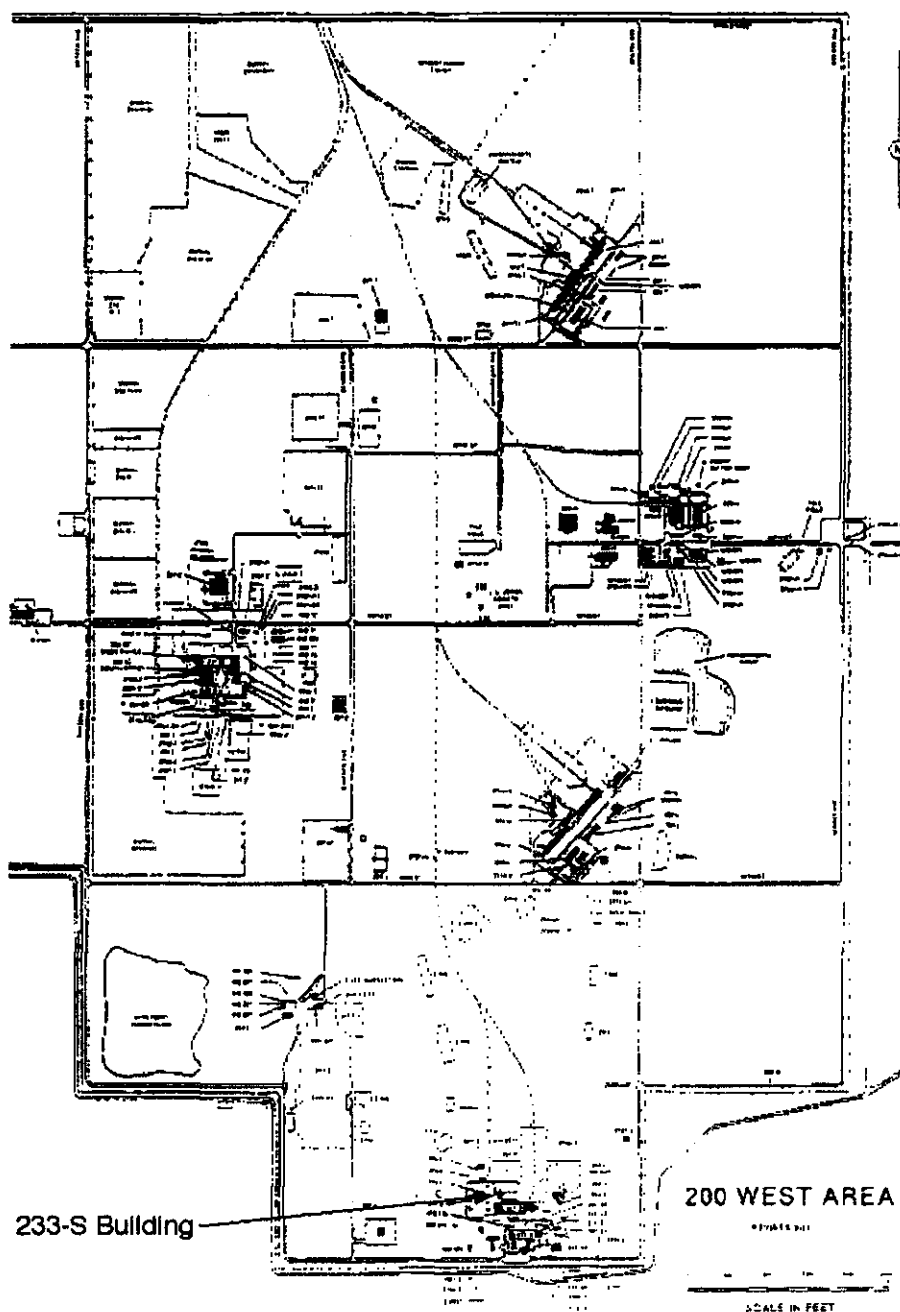
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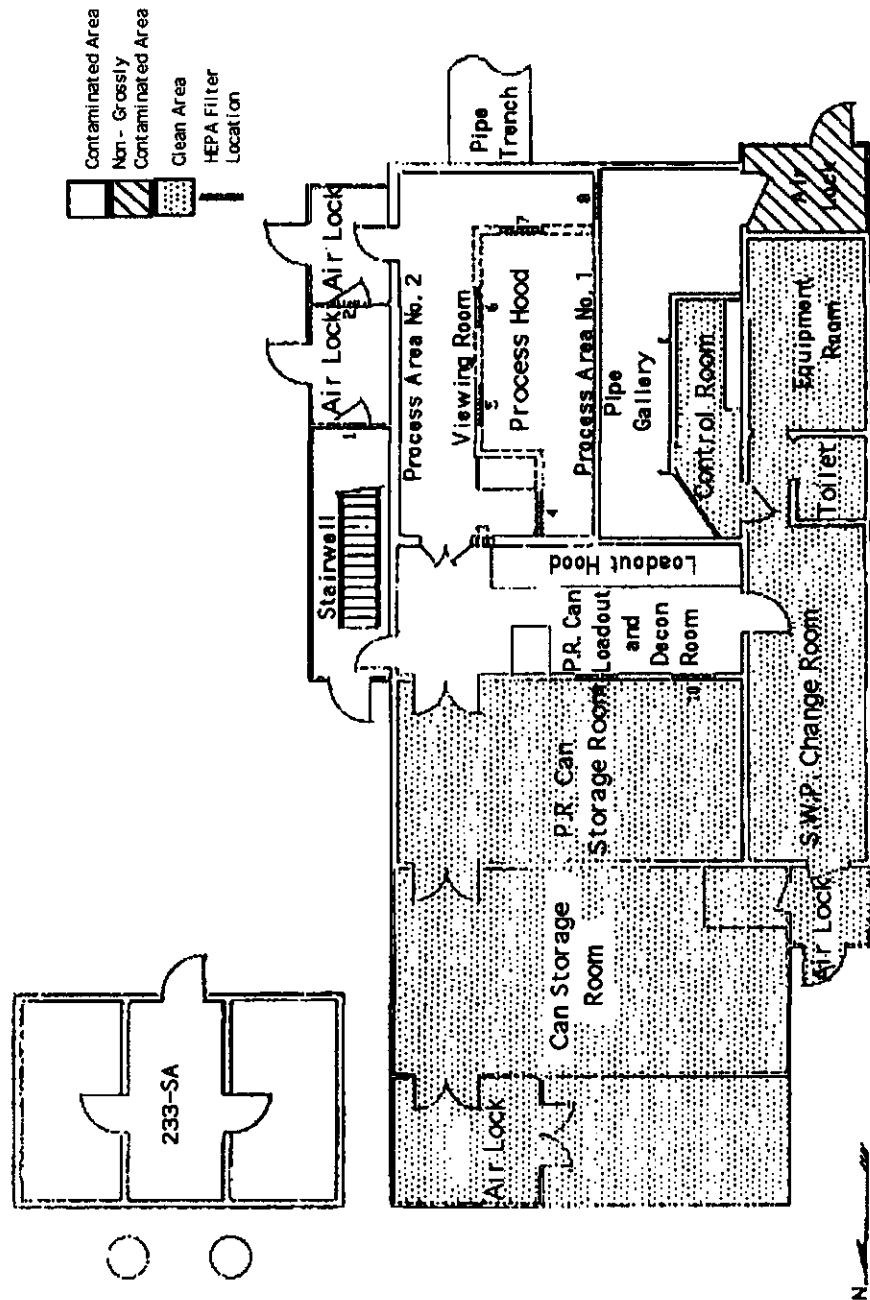
200 West Area, Hanford Site



200 West Area



200 West Area



Floor Plan 233-S Building (1995)



**ENDNOTES:**

<sup>0</sup> GE Hanford Co., HW-18700-DEL, pp. 702-711.

<sup>1</sup> Christy, HW-49121-DEL; and Rohrmann, HW-26186; and Bradford and Curtis, HW-30613; and Hanford Site Drawing H-2-7202; and Harmon, "Project CA-535..."; and G.E. Hanford Co., HW-39900-DEL, pp. 19-20.

<sup>2</sup> Harmon, "Project CA-535..."; and Sloat, HW-27796; and Rohrmann and Ludlow, HW-27968; and G.E. Hanford Co., HW-39900-DEL, p. 20.

<sup>4</sup> Ryan and Wheelwright, "Application of Anion Exchange...", P/1915, pp. 137-142; and Ryan and Wheelwright, HW-55893. See also: Ryan, "Chemistry of Plutonium in Anion Exchange Applications," in TID-7607; and Oberg and Swift, HW-SA-2290.

<sup>4</sup> The Higgins Continuous Ion Exchange Column was patented by Irwin R. Higgins, as an individual. The name of this equipment remained "Higgins," no matter which company or laboratory built the physical device.

<sup>5</sup> Higgins and Roberts, "A Countercurrent Solid-Liquid...", pp. 87-90; and Higgins, ORNL-1907.

<sup>6</sup> Roemer, WHC-SD-HS-SAR-001, Rev. 5, Appendix B; and Carr, HW-24800-105, p. 40; and Swift, "Continuous Anion Exchange Processing...", in TID-7607.

<sup>7</sup> Gustafson, HW-58461; and Fecht, "Improved Resin Handling, PUREX Plutonium Anion Exchange System," April 1960; and Battey, HW-63660; and McKee, "Meeting Minutes...", October 6, 1960; and Travis, "Reliability Improvements...", May 12, 1961; and Geier and Rathvon, HW-67800; and Roemer, WHC-SD-HS-SAR-001, Rev. 5, Appendix B; and Swift, "Continuous Anion Exchange Processing...", in TID-7607, p. 21; and Oberg and Swift, HW-SA-2290.

<sup>8</sup> Shaw, "REDOX Birch Recovery;" and Finch, HW-68026; and Shaw, "Physical Completion Notice, Project CGC-913;" and Kennedy, "Project Birch - CGC-913 As-Built Drawings;" and Yoder, "233-S Information Manual."

<sup>9</sup> Yoder, "233-S Information Manual."

<sup>10</sup> Koberg, HW-43964-DEL; and Vanderbeek, HW-43990.

<sup>11</sup> Investigating Committee, BNWL-10011, Part I, DEL, Sections I, II.

<sup>12</sup> Ibid., pp. VI-1, VI-4-5.

<sup>13</sup> Ibid., p. V-5; and Ballinger and Hall, PNL-6964 HEDR, p. 4.21.

<sup>14</sup> Falk, HW-42687; and Lyneis, "Construction Work Authorization, Project CG-692..."; and Bergdahl, "Physical Completion Notice, Project CG-692."